"Whale Shark Expedition": Observations on *Rhincodon typus* from Arta Bay, Gulf of Tadjoura, Djibouti Republic, Southern Red Sea

by

Danilo REZZOLLA (1) & Tiziano STORAI* (2)

ABSTRACT. - The present work is the report of two ecotouristic expeditions carried out in the Gulf of Tadjoura (Djibouti Republic, Southern Red Sea) and having as main objectives a contribution to the increasing of biological and ecological knowledge about whale shark *Rhincodon typus* (Smith, 1828) in these waters by means of observations and photo-identification tools. The survey was conducted for five days in January-February 2007 and for six days in January 2009, recording a total of 55 encounters (89% of which occurring in Arta Bay) with 32 juvenile whale sharks. Nineteen of them were males, five were females; it was not possible to determine the sex of eight of them. The estimate total length of these specimens ranged from 300 to 500 cm, averaging to 431 cm. Cooperating with Ecocean Whale Shark Photo ID Program, a 450 cm male, already photographed in 2005 and in 2006, was seen again also in 2007, contributing to hypothesize a philopatric instinct in whale sharks participating to the Djibouti seasonal feeding aggregations. Feeding strategies were observed, either in presence of abundant food source, or with depleting zooplankton bloom. Investigations about the trophic relations and observations about environmental influence on their abundance have been carried out. According with scientific literatures, a pattern of eight models of interaction with humans (CIH) have been used as a tool for a preliminary evaluation on shark tolerance towards the ecotourism impact in the area.

RÉSUMÉ. - "Whale Shark Expedition" : Observations de *Rhincodon typus* dans la baie d'Arta, golfe de Tadjoura, République de Djibouti, mer Rouge méridionale.

L'étude présente le rapport de deux expéditions d'écotourisme réalisées dans le golfe de Tadjoura (République de Djibouti, sud de la mer Rouge), avec comme principaux objectifs l'enrichissement des connaissances biologiques et écologiques du requin baleine *Rhincodon typus* (Smith, 1828) dans ces eaux au moyen d'observations et de photo-identification de spécimens. Les recherches effectuées durant cinq jours en janvier-février 2007 et durant six jours en janvier 2009, ont permis 55 rencontres (89% dans la baie d'Arta) dont 32 jeunes requins-baleines. Dix-neuf étaient des mâles, cinq étaient des femelles, et pour les huit restants il ne fut pas possible de déterminer le sexe. L'estimation de la longueur totale de ces spécimens varie de 300 à 500 cm, avec une moyenne de 431 cm. La coopération avec Ecocean Whale Shark Photo ID Program a permis en 2007 l'identification d'un mâle de 450 cm, déjà photographié en 2005 et en 2006, contribuant ainsi à l'hypothèse d'un instinct philopatrique des requins baleines lors de la saison d'aggrégation pour l'alimentation à Djibouti. Les stratégies d'alimentation ont été observées en présence d'une abondante source de nourriture ainsi que lors de l'épuisement du bloom de zooplancton. Les relations trophiques ont été étudiées ainsi que l'influence de l'environnement sur l'abondance des individus. En accord avec la littérature, huit modèles d'interactions avec l'homme (CIH) ont été utilisés comme outil pour l'évaluation préliminaire de la tolérance du requin baleine vis-à-vis de l'écotourisme pratiqué dans la zone.

Key words. - Rhincodontidae - *Rhincodon typus* - Whale shark - Red Sea - Djibouti - Field observations - Photo-identification - Ecotouristic expeditions.

Whale Shark, *Rhincodon typus* (Smith, 1828) is a giant suction-filter feeder shark (Compagno, 2001), living in epipelagic and neritic zone of tropical and warm-temperate waters in the world (Colman, 1997; Compagno, 2001) except the Mediterranean. It is a long-lived and highly vagile species (Compagno, 2001; Martin, 2007), and because of these aspects, whale sharks result challenging subjects for a long-term behavioural and/or ecological field study. In spite of increasing of knowledge during the last 20 years about morphology, seasonal aggregation, feeding mechanism, life history, distribution, and estimated abundance (Colman, 1997; Martin, 2007; Stevens, 2007) many biological and ecological topics related to this taxa, such as reproductive behaviour, philopatric instinct and genetic stocks structure, are still largely unknown. For this reason, all chances to add set data and information on this vulnerable species (Fowler, 2000; Norman, 2000; Pravin, 2000; CITES, 2002; Theberge and Dearden, 2006) have to be exploited.

Along Djibouti coasts (Southern Red Sea) anecdotical reports concerning either occasional presence of single

(1) Acquario e Civica Stazione Idrobiologica di Milano, Viale Gadio 2 20100 Milano Mi, ITALY. [info@danishark.it]
(2) DNAcquA Laboratorio di ricerche e studi sulla vita marina, Via San Carlo Borromeo 1, 09100 Cagliari CA, ITALY. [t.storai@alice.it]
* Corresponding author

whale sharks during the whole year, or seasonal aggregations of juveniles have been recorded (Rogerson, 2006), but recent scientific and ecotouristic expeditions performed in these waters (Rowat *et al.,* 2007; Rezzolla and Storai, unpubl. data), allowed to determine the seasonality of the juveniles aggregation and the formulation of a proposal for the inclusion of Djibouti waters in the whale shark monitoring framework of the Indian Ocean region (Rowat, 2007).

The present work is the report of the expeditions carried out in 2007 and in 2009 in the Gulf of Tadjoura, Djibouti Republic having as main object the contribution for the Ecocean Whale Shark Photo ID Program (http://ecocean.org), the observation of the shark behaviour and their eventual social interactions, the investigation of the feeding strategies, with particular attention to the trophic basis of the species, and at least a preliminary evaluation of the ecotourism pressure effects on sharks' behavioural pattern, based on the observed interactions between sharks and snorkelers.

MATERIALS AND METHODS

The Gulf of Tadjoura is localized in the Southern Red Sea, along the coasts of Djibouti Republic, 30 km from the border of Eritrea, 18 km from Somalia and 25 from Ethiopia. Particularly, the area of research was represented by the zone near Arta Bay (Figs 1A-C), a bay about 1 km wide, orientated from northwest to southeast, on the southern side of the western edge of the Gulf of Tadjoura. The zone is characterized by low, sandy and desert coasts, with scarcely deep waters, having a high primary production, caused by a coastal upwelling phenomenon. The diving points of observation are localized before Arta Beach (11°34'N, 42°49'E), Ras Korali (11°34'N, 42°47'E) and Escape Bay(11°34'N, 42°49'E), in a random range starting from 100 m offshore. In these sites the depth of the water is variable between 2 and 35 m, and the bottom is mainly a sandy and muddy undulate sprawl. Only in Ras Korali seabed some little madreporic rocks are present.

Two periods of survey have been provided from 29th of January to 3rd of February 2007 and from 23rd to 28th of January 2009, for a total of 11 days (5 days in 2007 and 6 in 2009 period). The base of the researchers during both expeditions was the 29 m M/Y "Elegante", motorized Iveco with two 400 hp motors. For monitoring activities in the Gulf, two Zodiacs of 5 m motorized with 40 hp, offshore motor have been used. Videos and photographs have been realized by camcorder Panasonic NV-GS 250s, 3CCD model, with NIMAR underwater covering.

Other utilized instruments were an optical densimeter Milwaukee and a digital thermometer Sharp PH Temp. WP model to record daily physical parameters of the water; a netset of 4 micron, for zooplankton samples harvest during feeding activities of whale sharks and a 100 cm long telescopic steel spear used to estimate the total length (TL) of individuals. The estimated TL of the sharks encountered and photographed, has been obtained comparing an image of the whale shark (or a large portion of it) with a snorkeler swimming alongside, keeping the 100 cm spear parallel to the

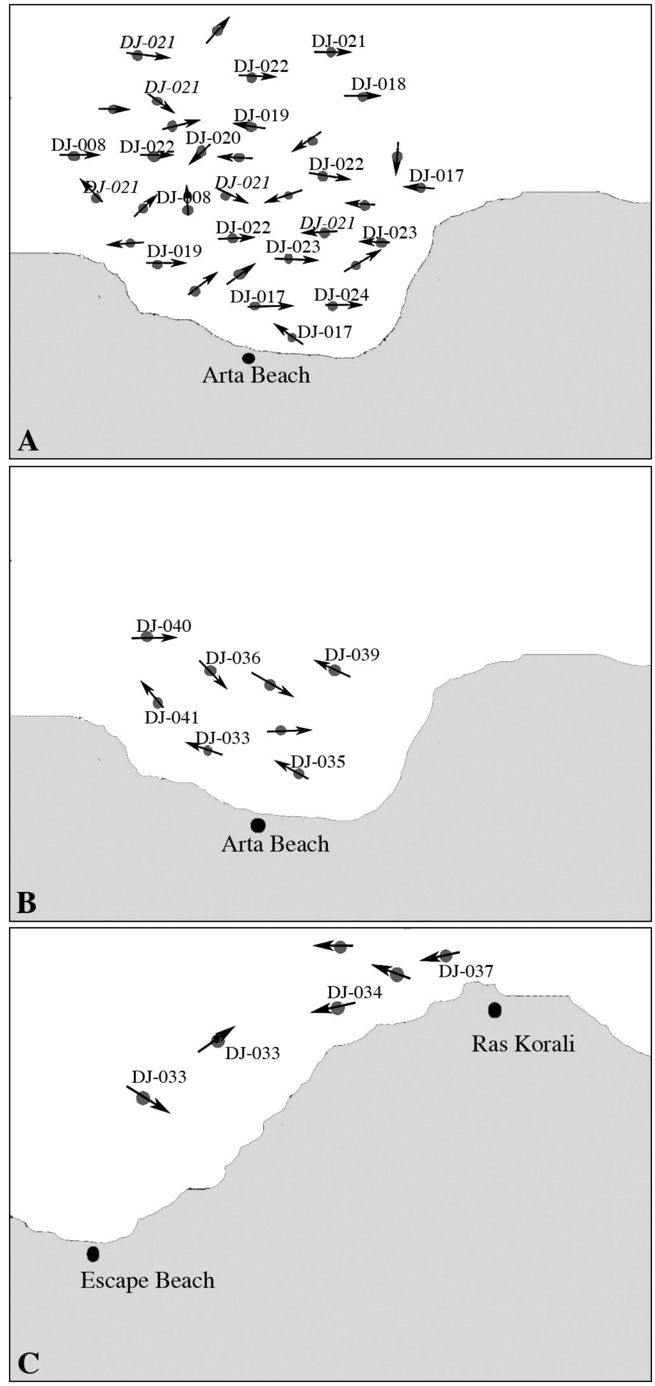

Figure 1. - Maps of research zone with relatives GPS encounters recording and swimming direction of the encountered whale sharks. **A**: Arta Bay, 2007; **B**: Arta Bay, 2009; **C**: Ras Korali and Escape Bay, 2009.

Figure 2. - Comparative method for whale shark TL estimation.

shark body (Fig. 2).

Each encounter has been recorded on a logsheet, following Maldives Whale Shark Expedition (2006) model. In the logsheet, the following informations have been collected:

a) Physical conditions both above and below the water (temperature, salinity, sea state and visibility); b) Depth on first encounter, taken from the base of the dorsal fin of the shark; c) Time at beginning and end of the encounter; d) Global Positioning System (GPS) coordinates at the start and end of the encounter to track direction of travel; e) A profile of the shark, including estimated size, gender and distinguishing features; f) Behaviour of the shark and eventual reaction to observer presence.

During some foraging events, samples of plankton floating in the path of the sharks have been collected. The samples, preserved in a 60% alcohol solution, have been sent to Dr. Mohsen M. El-Sherbiny Omar, Marine Science Department of Faculty of Science of the Suez Canal University, Ismailia, Egypt, for the taxonomic classification.

To protect both snorkelers and whale sharks during the encounters the code of conduct for whale shark tourism operations developed by Western Australian Department of Conservation and Land Management (http://www.calm.wa.gov.au/tourism/whalesharks_swimming.html) (NHT, 2005) has been followed. Particularly, the obstruction of swimming path of the shark and the use of underwater strobe flash have been avoided.

Following the main whale shark photo-identification methods (Arzoumanian *et al.*, 2005; Meekan *et al.*, 2006; Pierce, 2007; Speed *et al.*, 2007; Holmberg *et al.*, 2008) a lot of images have been obtained. Many of them were focused on the upper and lower fifth gill slit and the inner trailing edge of the pectoral fin. Approximately, this area of the shark body appears as a two-dimensional surface, containing evident distinctive spots and including suitable reference points for software or visual comparison. To allow a better identification of each individual, when possible, photos of both right- and left-side of each encountered shark have been shot. Also scars or images of distinctive features and the details of the pelvic region of each shark have been collected.

Selecting the best images of each single encountered shark, the photos have been sent to Ecocean database for photo-identification process, based on the algorithm of the dermal spots pattern (Arzoumanian *et al.*, 2005; Holmberg *et al.*, 2008). Ecocean returned results of identification process, attributing, where possible, a code of identification (i.e., DJ = Djibouti; 008, 017 etc. = progressive number) for each shark. TL, sex and date of sighting have been used to identify sharks in absence of the Ecocean identification code.

Videos and logsheet annotations have been analysed to recognize the most significant shark responses in reaction or in association with the presence of snorkelers during each encounter. From literature (Norman, 1999; Compagno, 2001; Martin, 2007; Quiros, 2007), eight main kinds of interactions have been codified: Mouth distension (MD), when shark show from closed mouth to fully open on a six-point scale, usually related to feeding); approach (A), when the whale shark swims quite closely, as though investigating out of curiosity and sometimes it tolerates being touched by snorkelers without exhibiting defensive reactions ; eye-rolling (ER) has been observed when the distance between snorkelers and shark head is about 3 m or less and the shark seems to follow snorkeler movements; purposing (P), movement away from the observer, but not out of sight. These models have been considered as "neutral behaviour" (Quiros, 2007). Include diving (ID), when sharks descend out of view of the snorkelers; changes in speed (CS), when shark passes from slow swimming to faster, pulling away from the snorkelers; change in direction (CD), when the shark suddenly changes swimming direction noticing the snorkeler presence; banking (B), in which the shark rolls and presents its dorsal surface towards the observer. These others have been considered as "avoid behaviour" (Quiros, 2007). Other codified behaviours quoted in literature as the roll eye tailward (Martin, 2007) or coughing/gill flushing (Norman, 1999) have not been observed.

Four natural whale shark behaviour proposed by Nelson and Eckert (2007), passive foraging behaviour (PF), vertical foraging behaviour (VF), active foraging behaviour (AF) and cruising behaviour (CB) have been categorized as well.

Crossing the eight codified interactions with human (CIH) with four natural behavioural pattern for whale sharks, a preliminary linear model has been proposed as possible evaluating index of behavioural distress over Djibouti whale shark aggregation.

RESULTS

Environmental parameters

The main environmental parameters (atmospheric tem-

perature, water temperature, water salinity) have been daily recorded and they appeared without significant variations during both 2007 and 2009 whole periods and for the whole research zone. The air temperature was of 29°C, with a decrease of 1°C during the raining days (25-26 Jan. 2009). The sea surface temperature (SST) was comprised between 26.4°C and 27°C during the both whole 2007 and 2009 periods. A mean decrease of 1°C of the water temperature has been recorded on a depth of 6 meters.

In 2007 the surface salinity was 30 ppt, while in 2009,

Table I. - Synoptical table of encounter with whale sharks during expedition in 2007. HE/D = Hour of encounter/Duration; Sex = (M) male; (F) female; (ND) not determined. AF: active foraging behaviour; CB: cruising behaviour; VF: vertical foraging behaviour; for other abbreviations, see text.

Date	HE/D	Sex	TL (cm)	Code	Location	Depth of encounter	Behaviour	CIH
29 Jan	11:15/2’	M	400	DJ-017	Arta	<1	AF	B
	11:26	ND	400	-	Arta	<1	AF	B
	11:35	M	450	-	Arta	<1	AF	MD
	11:45/5’	ND	400	DJ-018	Arta	<1	VF	CS
	11:50/9’	M	450	DJ-019	Arta	<1	VF	ID
	12:04	F	450	-	Arta	<1	AF	MD
	12:25	M	450	-	Arta	<1	VF	A
	15:29	M	450	-	Arta	<1	AF	ER
	15:30/8’	M	450	DJ-020	Arta	<1	AF	MD
	15:50	F	450	-	Arta	<1	VF	CS
	16:00/9’	M	450	DJ-021	Arta	<1	AF	P
30 Jan	10:00	M	450	DJ-021	Arta	<1	AF	B
	10:15	M	450	DJ-021	Arta	<1	AF	A
	10:24	M	400	-	Arta	<1	VF	P
	10:30	M	450	DJ-021	Arta	<1	AF	ER
	10:35	M	450	DJ-021	Arta	<1	CB	ID
	10:45/9’	M	400	DJ-022	Arta	<1	VF	A
	10:55/6’	M	400	DJ-022	Arta	<1	VF	P
	11:08	M	400	DJ-022	Arta	<1	AF	MD
	11:10	M	400	DJ-022	Arta	<1	AF	P
	11:13	M	400	DJ-022	Arta	<1	AF	CS
	15:35	M	400	DJ-017	Arta	<1	AF	ER
	15:42	ND	400	-	Arta	<1	AF	B
	16:10	ND	400	-	Arta	<1	AF	MD
	16:15	M	400	-	Arta	<1	VF	P
	16:28	M	400	-	Arta	<1	AF	MD
31 Jan	08:30/4’	F	500	DJ-026	Arta	<1	VF	B
	8:38	F	500	-	Arta	<1	CB	P
	8:42	M	450	DJ-021	Arta	<1	VF	B
	8:48	M	450	-	Arta	<1	AF	MD
	9:02	M	450	-	Arta	<1	AF	MD
	9:15	F	500	-	Arta	<1	VF	ER
	9:25	M	400	DJ-022	Arta	<1	AF	MD
2 Feb	11:30	M	450	DJ-008	Arta	<1	AF	P
	11:32	M	450	DJ-008	Arta	<1	AF	P
	16:47	M	450	DJ-019	Arta	<1	CB	ER
3 Feb	8:10	M	400	DJ-023	Arta	<1	AF	MD
	08:15/1’	M	400	DJ-023	Arta	<1	AF	ER
	11:15	F	400	DJ-024	Arta	<1	AF	P
	11:17/2’	F	400	DJ-024	Arta	<1	VF	P
	11:20	M	400	DJ-023	Arta	<1	AF	ER

Date	HE/D	Sex	TL (cm)	Code	Location	Depth of encounter	Behaviour	CIH
23 Jan	13:15/7’	M	400	DJ-041	Arta	<1	AF	A
	16:00/8’	M	350	DJ-033	Escape	<1	AF	CS
	16:30/8’	M	350	DJ-033	Escape	<1	AF	MD
	17:30/4’	M	450	DJ-036	Arta	<1	CB	CD
	20:36/34’	M	300	DJ-034	Ras Korali	<1	CB	ER
	20:45/15’	ND	450	-	Ras Korali	<1	PF	B
24 Jan	8:45/1’	ND	350	-	Ras Korali	-8	AF	ID
	15:45/2’	F	450	DJ-035	Arta	<1	AF	MD
	16:02/4’	M	350	DJ-033	Arta	<1	AF	A
	16:10/7’	M	350	DJ-039	Arta	<1	CB	A
25 Jan	11:06/3’	M	400	-	Arta	<1	AF	MD
	11:42/4’	ND	400	DJ-040	Arta	<1	PF	CS
	12:57/5’	ND	350	-	Arta	<1	PF	CD
26 Jan	16:39/8’	M	400	DJ-037	Ras Korali	<1	CB	ID

Table II. - Synoptic table of encounter with whale sharks during expedition in 2009. HE/D = Hour of encounter/Duration; Sex = (M) male; (F) female; (ND) not determined. See table I and text for abbreviations.

Table III. - Re-sight whale sharks in the Arta Bay zone during 2007 and 2009 expeditions.

Ecocean code or individual	Sex	Date	Number of sightings	Intervals among further sightings
DJ-021	M	30 Jan. 2007 30 Jan. 2007 31 Jan. 2007	6	1071’ 15’ 15’ 5’ 1317’
DJ-022	M	30 Jan. 2009 31 Jan. 2009	6	1’ 7’ 2’ 3’ 1277’
DJ-033	M	23 Jan. 09 24 Jan. 09	3	22’ 1404’
DJ-008	M	2 Feb. 07	2	2’
DJ-017	M	29 Jan. 07 30 Jan. 07	2	1676’
DJ-019	M	29 Jan. 07 2 Feb. 07	2	5821’
DJ-023	M	3 Feb. 07	2	5’
DJ-024	F	3 Feb. 07	2	2’
TL 450	M	29 Jan. 07	2	184’
TL 450	M	31 Jan. 07	2	14’
TL 400	M	30 Jan. 07	2	13’
TL 450	F	29 Jan. 07	2	216’
TL 500	F	31 Jan. 07	2	37’
TL 400	ND	29 Jan. 07	2	19’

may be for the rain, the salinity recorded was 28-30 ppt. The abundant fouling renders the water very turbid, limiting the underwater visibility at no more than 6 m.

Records of encounters

During the 60 hours of efforts spent in effective survey, 55 encounters occurred (Tabs I, II), with an average of 0.93 encountered shark/hour, concerning a total of 32 specimens, (N 2007 = 20; N 2009 = 12). 41 encounters have been recorded in the 2007 expedition (with an average of 1.41 encountered shark/hour), 14 in 2009 (average of 0.45 encountered shark/hour). In the 2007, 13 individuals (65%) have been seen again. Eleven sharks have been seen twice and two individuals have been encountered six times (Tab. III). In 2009 only one specimen (8.33%) has been observed in three occasions, twice (23 Jan. 2009) at Escape Bay and the following day at Arta Bay. Five male sharks (35.71% of the sharks met again; N = 14) have been seen in two or more different days, with a mean re-sighting interval of about 15 hours.

The 71.43% of re-sight sharks were males, the 21.43% were females and the 7.14% were undetermined. In three occasions in 2007, almost two individuals were contemporaneously seen cruising or feeding in the same zone and in one occasion it occurred after the sunset (night on 23 Jan. 2009). More than 56% of encounters occurred in the morning (from 08:00 to 13:00), with a cuspid of sightings (40%) between 10:00 and 12:00 (Fig. 3). One encounter of 2009 occurred at a depth of 8 m while all the others occurred with the sharks swimming close to the surface. All 41 encounters recorded during the 2007 expedition occurred in the waters of Arta Beach, which is the mostly frequented site by whale sharks with a total of 49 encounters (89.10%), while four sightings

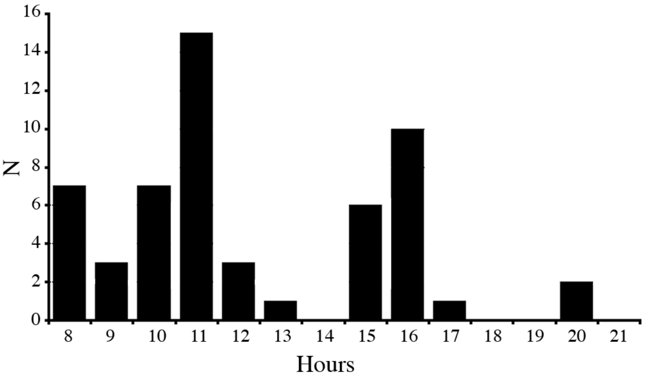

Figure 3. - Daily index of frequency of whale shark encounters (N = 55).

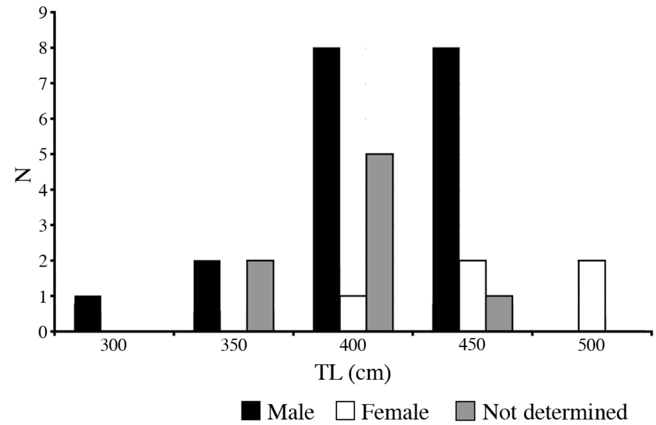

Figure 4. - Sex and size frequency of the whale sharks in the Arta Bay, Ras Korali, Escape Bay zone (N = 32).

(7.27%) have been recorded at Ras Korali and two (3.63%) at Escape Bay.

Demography structure of the seasonal stock and size of individuals

Of the recorded specimens, 19 (59.38%; N = 32) were males, five (15.62%) were females and for eight of them (25%) it has not been possible to determine the sex, but for size, they were considered juvenile (Compagno, 2001; Martin, 2007; Norman and Stevens, 2007). Even if in Djibouti waters the seasonal aggregations of whale sharks seem to have a dominance of immature males (Rowat *et al.,* 2007), their percentages resulting from the two expeditions were different. Actually, the percentage of males was 75% (N = 16) in 2007, while it was 87.5% (N = 8) in 2009. In 2007 the minimum estimated TL recorded at Arta Bay zone was a 400 cm male while in 2009 it was a 300 cm male. The maximum estimated size was recorded for two 500 cm females encountered in 2009. The largest peak in numbers for the estimated TL occurring at 400 cm (43.75%) and a smaller second peak in abundance (34.37%) at 450 cm (Fig. 4), with a total mean TL of 431 cm (N = 32; ± SD 0.79). It substantially confirms the average in TL of 447 cm ± 84 cm, quoted in Rowat *et al*. (2007).

Resulting for Ecocean photo ID library

During a total of 165 minutes of encounter with the whale sharks, 138 minutes of film have been realized and 334 digital images have been obtained. Of these, 176 (52.69%) have been sent to Ecocean library for individual identification. In the 76.36% of cases both right and left side images of the approached sharks have been obtained, in the 12.72% of cases only the dx side and in the 11.08% only the sx side have been taken. About sharks having particular features (marks, scars, injures, cuts etc.) 11 of 20 (55%) encountered individuals presented them in 2007, while in 2009 50% of the specimens showed them. In 2007, nine specimens (45% of those encountered) have been identified as a "new shark", so nine as in 2009 (75%).

Particularly interesting is the case of one of the sighted specimens (DJ-008). It was already photographed in Djibouti waters a first time on 26 Dec. 2005 and once again on 13 Nov. 2006.

Foraging ecological observations

In the period of 2007, the density of the zooplankton aggregations favoured active feeding behaviour similar to that described in Clark and Nelson 1997. In 2009, during three foraging events, a sample of zooplankton has been collected. The accurate classification of the samples revealed 21 taxa related to Holoplankton (Tab. IV) and various components of Meroplankton as *Polychaeta* larvae, Lamellibranch larvae, Decapod larvae, Echinoderm larvae, fish eggs and larvae.

Ecological interactions with other marine species

No interaction between whale sharks and other marine macrofauna has been observed in Arta Bay zone, during the whole survey periods. Thus, some specimens of Green Turtle (*Chelonia mydas*) have been observed swimming just below the surface in one of diving points off Arta Beach but in absence of whale sharks. Furthermore, anecdotic reports of manta rays (*Manta birostris*) have been collected. They were sighted few days earlier of the becoming of the expedition on the site.

Whale shark behavioural models and interactions with snorkelers (CIH)

Foraging behaviour has been recorded in the 87.27% of the encounters (AF+VF+PF in Tab. V). The most common observed feeding activity (68.75% of the foraging behaviour) was the active foraging while in the 25% of the record-

Table IV. - Classification of the zooplanckton present in the samples collected during active feeding of three whale sharks in Arta Bay. **: Common species; *: Uncommon species; No asterisk: rare species.

Holoplankton				Meroplankton
Foraminiferida	***Clausocalanus minor*	***Nanaocalanus minor*	**Amphipoda**	Polychaeta larvae
Globigerina spp.	*Clytemnestra scutellata*	*Oithona plumifera*	** Phronimidae	Lamellibranch larvae
Ostracoda	*Corycaeus ovalis*	*Oncaea media*	(mainly *Hypreria* spp.)	**Decapod larvae
Cypridina spp.	*Corycaeus speciosus*	*Oncaea scottodicarloi*	**Chaetognatha**	**Echinoderm larvae
Copepoda	**Corycaeus* spp.	***Oncaea clevei*	*Sagitta* spp.	Fish eggs
Acartia spp.	*Farranula gibbula*	***Paracalanus aculatus*	**Appendicularia**	Fish larvae
**Eucalanus subcrassus*	*Macrosetella gracilis*	*Paracalanus parvus*	*Oikopleura dioica*	

Table V. - Relationship between whale shark behavioural models (Nelson and Eckert, 2007) and CIH during encounters in Arta Bay zone (N = 55). See text for abbreviations.

Behavioural model	Neutral (67.27%)				Avoid (32.73%)			
	MD	A	ER	P	ID	CS	CD	B
Active feeding (60%)	13	3	5	5	1	2		4
Vertical feeding (21.82%)		2	117	4	1	2		2
Passive feeding (5.45%)						1	1	1
Cruising (12.73%)		1	2	1	2		1	

ed foraging behaviour the shark adopted the vertical suction technique (Fig. 5). This has been observed overall in 2007 expedition, in presence of high food concentration. In these occasions, passive feeding has been never observed. In 2009 period, with a progressively lower plankton concentration, passive foraging has been observed during three encounters (33.33% of the foraging behaviour of the period and 6.25% of total foraging behaviours).

Non-foraging behaviour occurred in the 12.73% of the cases. Apparently, in more than 2/3 of encounters (67.27%) the snorkeler presence did not create negative interferences with the neutral behaviour of the whale sharks.

DISCUSSION

Foraging aggregation of juvenile whale sharks in the Gulf of Tadjoura occurred in October-February period (Rowat, 2007; Rowat *et al.*, 2007; Rezzolla and Storai, unpublished data), with possible oscillations of the temporal arc due to variation of NE monsoon season. In this period, SST of Arta Bay ranged between 24°C and 29°C, optimal habitat condition for whale shark, generally encountered in worldwide waters having a similar range of temperature (Compagno, 2001; Martin, 2007), and for production of plankton and nektonic micro and mesofauna. Salinity appeared lower (28-30 ppt) than that recorded (34-35 ppt) in waters usually frequented by *R. typus* (Compagno, 2001).

The presence of sharks in the research area was strongly conditioned by food abundance. In fact, during the shorter survey period in 2007, characterized by a high zooplankton concentration, encounters with sharks were about 3 times more frequent compared to those occurred in 2009, when zooplankton blooms progressively depleted. All whale sharks observed during the two expeditions have to be considered immature or adolescent, according to Compagno (2001) who considers males as immature at 299 cm or less and adolescent at 390 to 540 cm.

In addition, no male showed claspers exceeding the pelvic fin length and/or evidence of mating damage, suggesting that the individuals were really immature or adolescent. Females are considered immature from 340 cm or less, to 760 cm (Compagno, 2001), while a pregnant female was recorded about 10.6 m long (Joung *et al.,* 1996).

About size structure of the whale shark stock encountered during the two expeditions, it is interesting to notice the short range in TL of Arta Bay population comprised between 300 and 500 cm (250-600 cm in Rowat *et al.*, 2007). The large percentages (75-87.5%) of immature males and the TL frequency seem to indicate a high degree of segregation by size and gender in Djibouti waters. Size segregation of populations seems typical of whale sharks as it has been recorded in many of the main study sites as Ningaloo Reef, Western Australia (Taylor, 1994; Meekan *et al*., 2006), Gladden Spit, Belize (Graham and Roberts, 2007; Martin 2007), South Ari Atoll, Republic of Maldives (Maldives Whale Shark Expedition, 2006), Seychelles (Rowat and Gore, 2007) and Gulf of California (Eckert and Stewart 2001; Cardenas-Torres *et al.,* 2007), and it may prevent adults to compete for food with juvenile conspecifics even if in the previously quoted sites the TL average and frequency of monitored sharks are in all larger than those recorded in the Gulf of Tadjoura. Also in Djibouti "Whale shark Expedition" photo-identification process has been applied, thanks to the cooperation with Ecocean organization. Photo ID is becoming an useful

Figure 5. - Whale shark adopting vertical foraging technique.

and always more diffuse tool of research for scientific and ecoturistic expeditions (Arzoumanian *et al*., 2005; Meekan *et al.,* 2006; Pierce, 2007; Speed *et al.,* 2007; Holmberg *et al.,* 2008). It has several advantages over other investigation instruments as, i.e., conventional tagging: it is a non-invasive methodology, it potentially reduces "avoid behaviour" response in the shark which may be sighted again (Pierce, 2007) and, at least, the comparison of images can be obtained either by free, automatic process, as i.e., Interactive Individual Identification System (I3S) (Meekan *et al*., 2006; Pierce, 2007; Speed *et al.,* 2007) or either by a central database elaboration as Ecocean library (Arzoumanian *et al*., 2005; Holmberg *et al*., 2008).

The photo-identification models for whale sharks, however, are entirely contingent on the assumption of permanence or long-term stability of the patterns of spots, stripes, and distinguishing features present on the lateral area behind the last gill slit (Arzoumanian *et al.,* 2005; Meekan *et al*., 2006). Therefore, this may not be true for all individuals or the spot and stripe patterns might change as a consequence of the shark growth, even if the spot and stripe pattern appears absolutely similar for embryos and adults (Garrick 1964; Joung *et al.,* 1996) and two individuals have been photographed and identified in Ningaloo Reef after more than a decade (Meekan *et al.,* 2006). Photo-identification studies contribute also to demonstrate that some whale sharks are philopatric, returning to the same site in subsequent years (Maldives Whale Shark Expedition, 2006; Meekan *et al.,* 2006; Graham and Robert, 2007; Rowat and Gore, 2007). In Djibouti waters, scientific monitoring is too recent to have developed data sets confirming this hypothesis, but the record DJ-008 concerning a male whale shark 450 cm in TL, photographed in 2005, in 2006 and on 2 Feb. 2007 in Arta Bay seems to sanction the philopatric instinct of Djibouti whale sharks, as well as several other individuals always recorded in January 2009 (Rowat, pers. comm.).

Among the behavioural models recognized in whale sharks of Tadjoura Gulf, swimming without apparently foraging motivations (non-foraging behaviour or cruising CB) occurred only in less than 13% of the encounters. During these events, the shark swims close to surface, at increased speeds (> 1.0 m/s) compared to speeds used while foraging (0.0-1.1 m/s) (Nelson and Eckert, 2007). Underwater observations confirmed that the cruising sharks were swimming linearly, with closed mouth, employing a sinuous propulsive stroke involving most of the posterior portion of the body to the pectoral fins (Martin, 2007), without no ram or suction filter feeding motion typical of foraging behaviour. Observations by Clark and Nelson (1997) suggest that whale sharks alter their swimming behaviour when they find an area with high concentration of plankton even if the sensorial mechanism – vision, olfactory, bioelectric receptors – or their combination allowing the individuation of food sources are still unknown.

Dimethyl sulphide (DMS), an oxious-smelling compound released during the trophic interaction between zoo and phytoplankton (Dacey and Wakeham, 1986), could be a chemical foraging attractive cue for whale sharks from relatively short distances (< 2 km) (Martin, 2007), but this needs to be tested experimentally. All foraging behaviors adopted by the whale shark have been observed during the two expeditions. These behaviours were grouped into "active" and "passive" (Taylor, 2007). During active foraging, (AF) whale sharks were observed feeding directly at the sea surface (Nelson and Eckert, 2007; Taylor, 2007), swimming through the dense aggregations of zooplankton, combining both suction and ram feeding techniques to collect prey. The whirlpools caused by suction and snout, dorsal and caudal

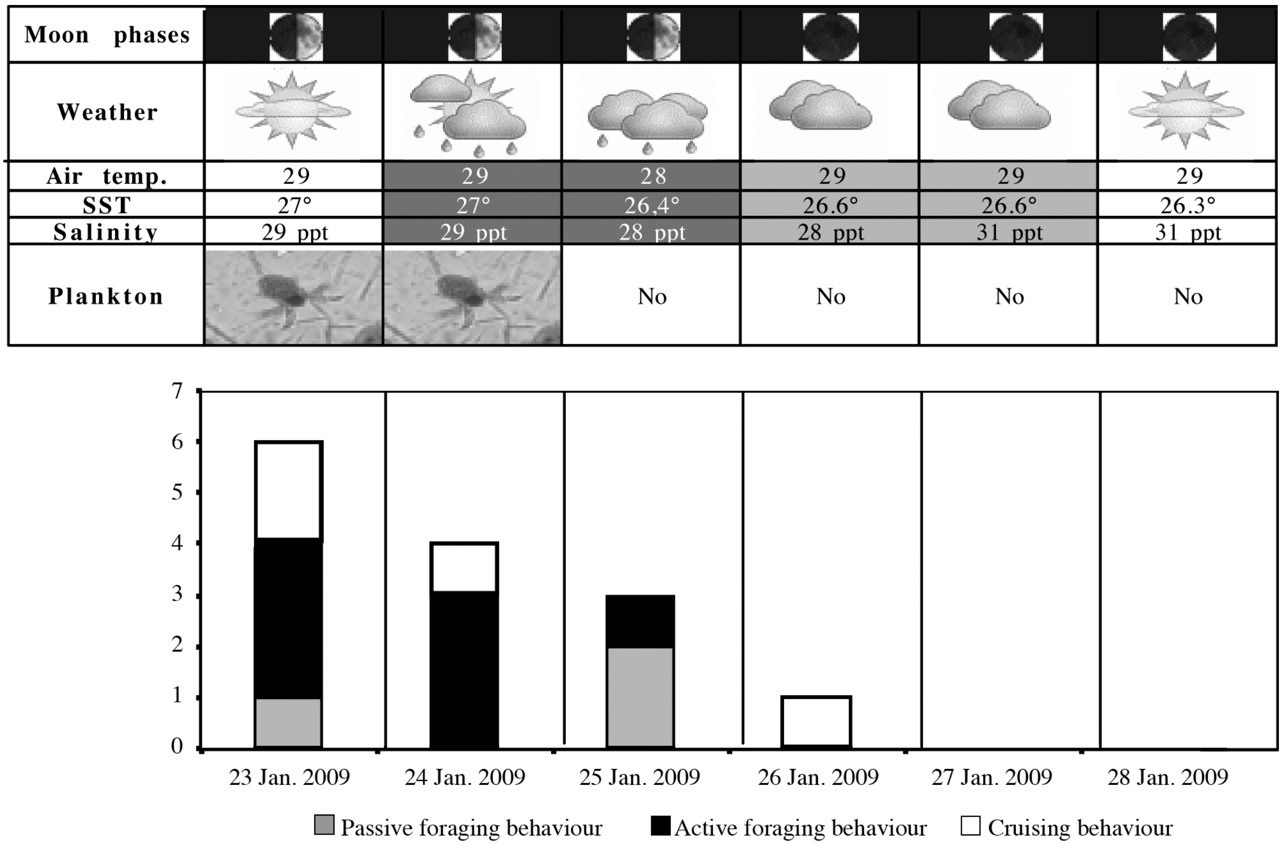

Figure 6. - Whale shark encounters in relation with moon phases, weather conditions, air temperature, SST, plankton aggregations in the zone of Arta Bay, during 2009 survey periods.

top fin breaking the surface were one of the main presence clues of a whale shark in the turbid waters of Arta or Escape Bay. Another active foraging model was represented by vertical feeding (VF). Adopting this technique, the body of the shark assumed an angle 30° to about 90° with sea surface, with its head at ± 1 m or less under the surface. In this position, the shark would float and gulp water using a suction technique. Its mouth took large gulps of water, closing the mouth for a few seconds after each gulp, and expelling water out the gills slits (Nelson and Eckert, 2007; Taylor, 2007). Usually, active foraging has been observed in presence of high concentration of food (Colman, 1997; Clark and Nelson, 1997; Compagno, 2001; Martin, 2007; Nelson and Eckert, 2007; Taylor, 2007) while passive feeding (PF) was adopted when food concentration was scarce. In this case, using a ram filter technique similar to that observed in basking shark (*Cetorhinus maximus*) (Sims and Quayle, 1998), the shark swam slowly (sometimes circularly) near the surface (but without to break it) with its open mouth: the water passed in it and through the gills. Every few minutes the mouth would close and the shark appeared to swallow (Nelson and Eckert, 2007).

Scientific literature quotes a large range of planktonic, benthonic and nektonic organisms as prey for whale shark. Coral spawn (Colman, 1997; Taylor and Pearce, 1999), snappers spawning (*Lutjanus cyanopterus* and *L. jocu*) (Heyman *et al.,* 2001) red crabs spawning (*Geocarcoidea natalis*) (Colman, 1997; Norman, 1999), tropical krill (*Pseudeuphausia latifrons*) (Taylor, 1994; Norman, 1999; Taylor, 2007), concentration of mysids (*Anisomysis spinata*) (Norman, 1999), eggs of teleosts (CITES, 2002) as tunas and lanternfish (*Diaphus* sp., Myctophidae) (Compagno, 2001), zooplankton, specifically Calanoid and Harpacticoid copepods (Norman, 1999), Copepods bloom (almost 13 species, mostly *Acartia clausi*)(Clark and Nelson, 1997), dense concentrations of chaetognaths, (Rowat *et al.*, 2007), crustaceans, specifically larval decapods (Norman, 1999), schools of small fishes as sardines, anchovies, mackerel, and even small tunas and albacore as well as squid (Taylor, 1994; 1996; Colman, 1997; Compagno, 2001; Heyman *et al.,* 2001; Wilson *et al.,* 2001; Wilson, 2002; Duffy, 2002; Graham and Roberts, 2007), shrimp blooms (Alava *et al.,* 2002) have been all recorded as target preys.

Table IV shows in details the zooplankton organisms

found in Arta Bay during three active foraging events involving whale sharks during 2009 expedition. Zooplankton usually aggregates near the surface by night and descends to deeper depths during the day (Folt and Burns, 1999) but, above all during 2007 expedition in Arta Bay, phyto and zooplankton formed dense swarms in surface waters, actively filtered by whale sharks during the daylight. Although no data on zooplankton dial vertical migrations (DVM) were available for the Gulf of Tadjoura area, it is possible that copepods and zooplankton in general reverse their usual DVM behavioural pattern (Rowat *et al.,* 2007) as simple response to food (phytoplankton) distribution and abundance (Zaret and Suffern, 1976) or that in the specific zone, zooplankton DVM does not occur (Van Couwelaar, 1997), as well as in near Somali waters.

In any case just at the half of the month of January in 2009 in both Arta Bay and Escape Bay there was still a massive presence of zooplankton and, consequently, of juvenile whale sharks as recorded by Dr. Rowat (pers. comm.). In that period, at Escape Bay, a large number (maybe 20) of individuals were contemporaneously observed while they were actively feeding upon large patches of zooplankton (S. Goggel, pers. comm.).

The oscillations of the season influence the zooplankton abundance (Van Couwelaar, 1997) and, consequently the presence of whale sharks (Wilson *et al.,* 2001; Duffy, 2002), but it is probable that other environmental factors, as daylight level, weather conditions, moon phases and/or upwelling contribution, play important roles in the structure and in the duration of the trophic chain having as apex the whale shark. Observations on some of these possible relationships have been synthesized in figure 6.

The earlier beginning of the rain season in 2009, coinciding with the depleting of the food source could be the start signal for migratory movements of the juvenile whale sharks aggregated in Tadjoura Gulf: in the last three days of survey, as figure 6 shows, a single cruising (non foraging) shark was encountered.

Interaction between *R. typus* and other “no target preys” marine species are little known. For example, traditional tuna fishermen have a long time fed back whale shark associations with schools of tuna in the Pacific and Caribbean (CITES, 2002), but also this could be considered a trophic interaction.

Predators upon newborns or juvenile whale shark include blue marlin (*Makaira nigricons*) (A. Goorah, cited in Norman, 2005) and blue shark (*Prionace glauca*) (Kukuyev, cited in Norman, 2005) while attacks against larger sized whale sharks have been recorded involving killer whale, (*Orcinus orca*) (O’Sullivan and Mitchell 2000) and recently, a large predator shark is a Great White (*Carcharodon carcharias*) or a Tiger Shark (*Galeocerdo cuvieri*) (Fitzpatrick *et al*., 2006). However, all these predators are absents or extremely rare in Djibouti waters. For this reason, the Gulf of Tadjoura seems to be a sure foraging site also for moderate sized (300 cm or less) individuals.

Evaluating the increasing phenomenon of whale shark ecotourism, two main kinds of interactions are usually taken in consideration: interactions with boats and with divers or snorkelers.

Recently, important progresses have been done to reduce the effects of the invasive presence of the humans on the natural behaviour of whale shark (Norman, 1999; Fowler, 2000; CITES, 2002; NHT, 2005; Cardenas-Torres *et al.,* 2007; Quiros, 2007), trying to involve the local community in the management of ecotouristic fluxes (CITES, 2002; Graham, 2004; Quiros, 2005; Cardenas-Torres *et al.,* 2007; Rowat and Engelhardt, 2007), often as economical alternative to harmful activities such as illegal whale shark fishing. In the Gulf of Tadjoura, the large military areas with numerous access restrictions and the desert nature of the coasts cause a low anthropogenic level, and consequently a scarce traffic of local boats. These conditions could be reducing the probability to have incidents involving whale sharks and boats. Therefore more than 50% of the individuals show scars correlated to impacts with boats or boat propellers and Rowat *et al*. (2007) quote a case in which a whale shark was cut by a military vessel. In any case, as observed scars on Arta Bay whale sharks were not recent and as no incidents occurred during the two expeditions, these interactions have not been considered.

Recognizing the reactions of the sharks to the swimming snorkelers around them, it is possible to hypothesize an empirical level of behavioural conditioning of the whale sharks (Martin, 2007; Quiros, 2007) and their degree of tolerance towards human activities. For this aim, a linear behavioural model has been obtained, crossing the four natural behaviours observed in whale sharks close to surface (Nelson and Eckert, 2007) with the main codified reactions to the human presence quoted in literature (Norman, 1999; Compagno, 2001; Cardenas-Torres *et al.,* 2007; Martin, 2007; Quiros, 2007) and here named CIH (Codified Interactions with Humans). The resulting high percentage (67.27%) of neutral behaviours could be evaluated as a corresponding low index of distress for the observed individual. MD (or no reaction) has been assumed as extreme CIH for neutral behaviour as well B as extreme CIH for avoid behaviour. From the scheme (Tab. V) it results that in 23.73% of the cases, sharks continued their feeding activities, even if the observer presence always generated avoid behaviour responses in the sharks involved in passive foraging activities. In all, only in 12.72% of the total cases sharks showed the stronger defensive attitude (banking). Analyzing these data, it is possible to evaluate the aggregating sharks in the Gulf of Tadjoura as not particularly suffering from human pressure. Obviously, this acceptable level of interaction can

be obtained only with a correct code of conducts (Norman, 1999; NHT, 2005; Cardenas-Torres *et al*., 2007; Quiros, 2007) followed by both scientific and ecotouristic expeditions during the approaches with the sharks.

The combination of slow growth, late sexual maturity, k reproductive model, migratory and philopatric habits make *R. typus* very vulnerable to population decline. Because nomadic habits of whale sharks, long-term field observations result logistically difficult and prohibitively expensive, so the only solution assuring a deployed and constant fluxes of observational data and documentation on the species could be represented by the synergy of ecotourists and biologists, as in many cases already well documented (Davis *et al.,* 1997; Davis, 1998; Norman, 1999; Graham, 2004; Quiros, 2005; Maldives Whale Shark Expedition, 2006; Cardenas-Torres *et al.,* 2007; Quiros, 2007; Rowat and Engelhardt, 2007; Holmberg *et al.,* 2008). In Djibouti waters, as all over the world, this cooperation may be the base for further studies focused on the little known aspects of the whale shark behavioural ecology, life history and on conservation policy.

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